

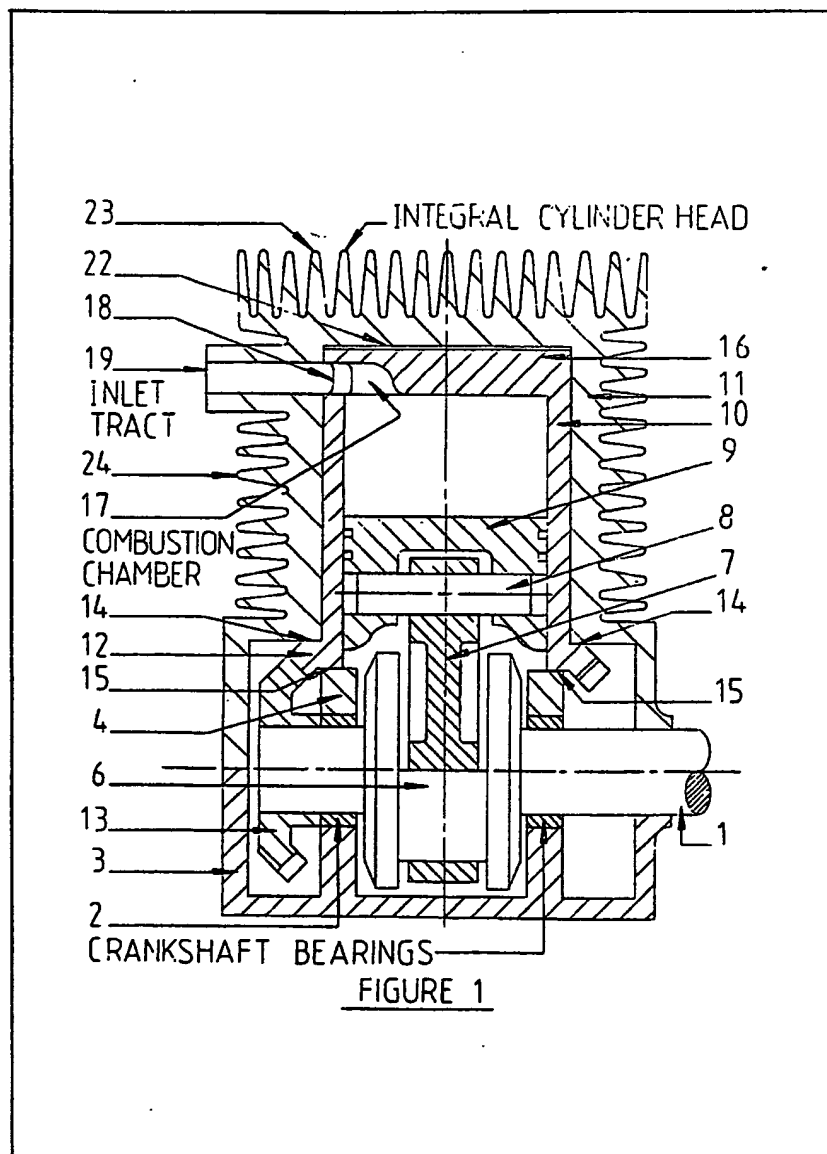
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(54) Rotary cylinder valve internal combustion engine

(57) The cylindrical sleeve 10 is constrained for rotational motion only within the cylinder block 11 and is rotated at a rotary speed in a predetermined relationship to that of the crankshaft 1 by gearing 12; 13 between the sleeve and crankshaft. The sleeve has at least one port 18 in its cylindrical wall which comes into alignment with an inlet port 19; an

outlet port; and an aperture for a spark plug or fuel injector provided in the wall of the cylinder at appropriate times during rotation of the sleeve and the crankshaft, so as to allow the induction of gas or fuel into the interior of the sleeve, ignition of such induced gas or fuel after compression thereof and venting of products of combustion from the cylinder during the exhaust stroke. The sleeve (36, Figs. 10 and 11) may house opposed pistons (38).



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

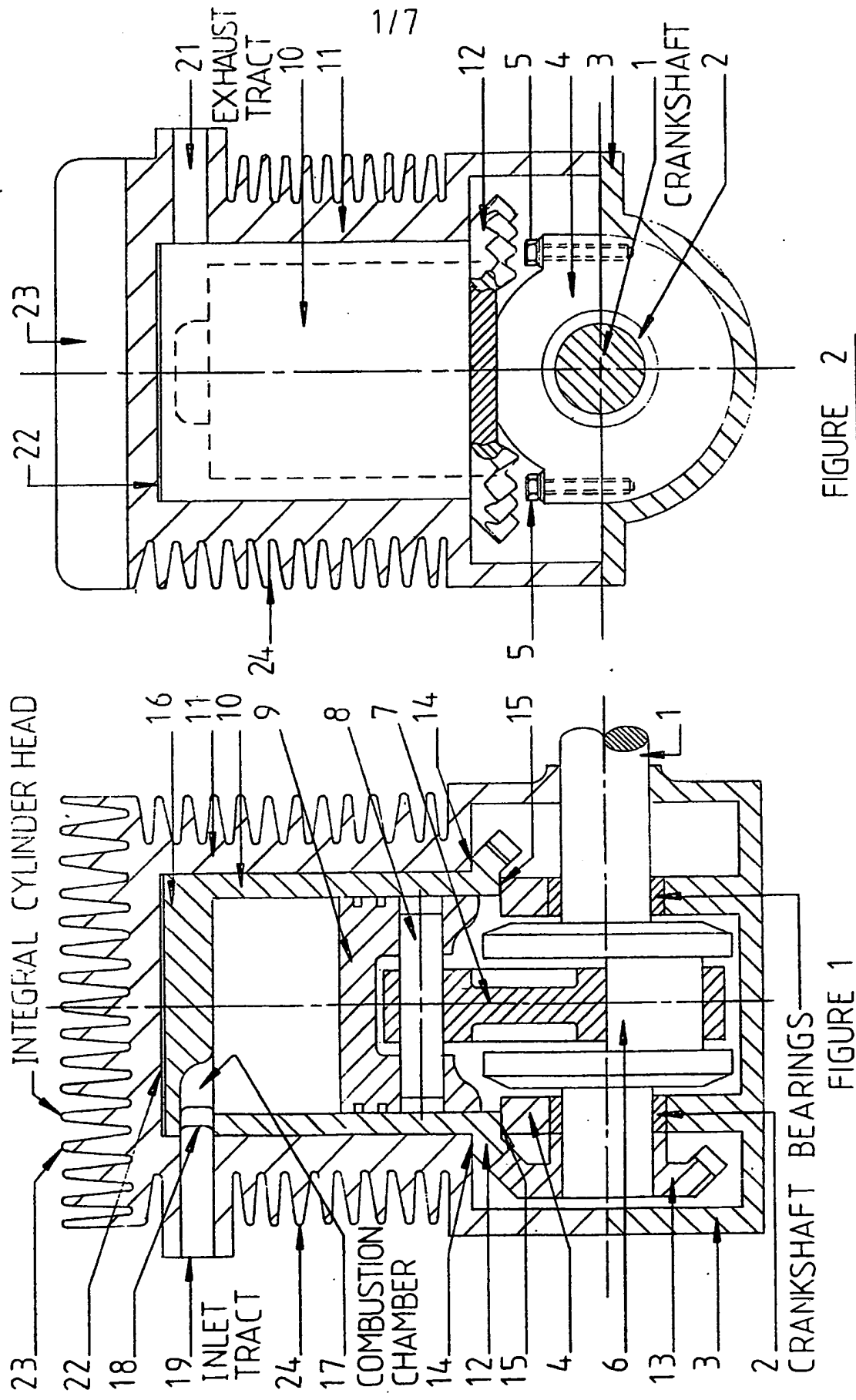
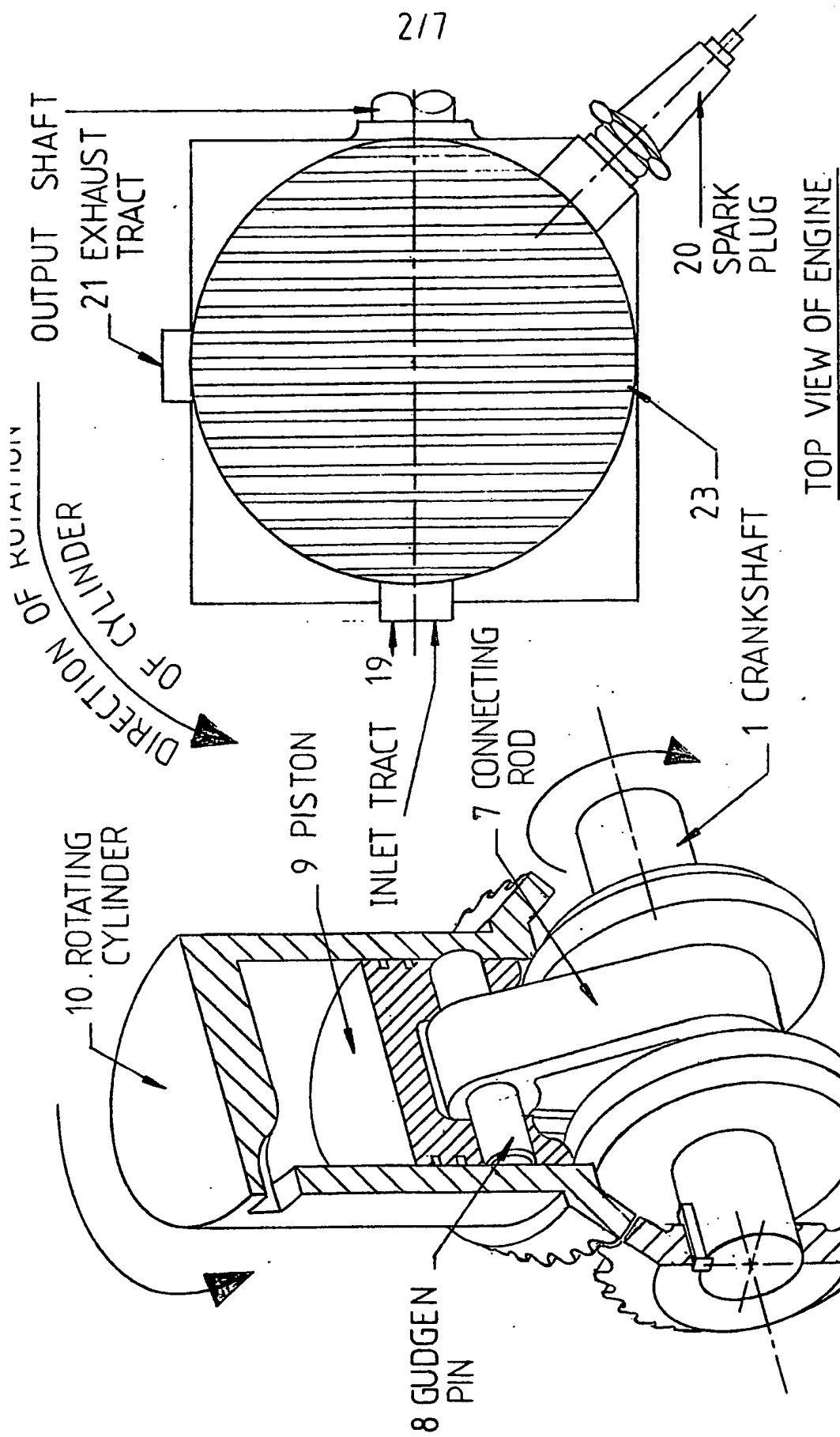


FIGURE 2

FIGURE 1



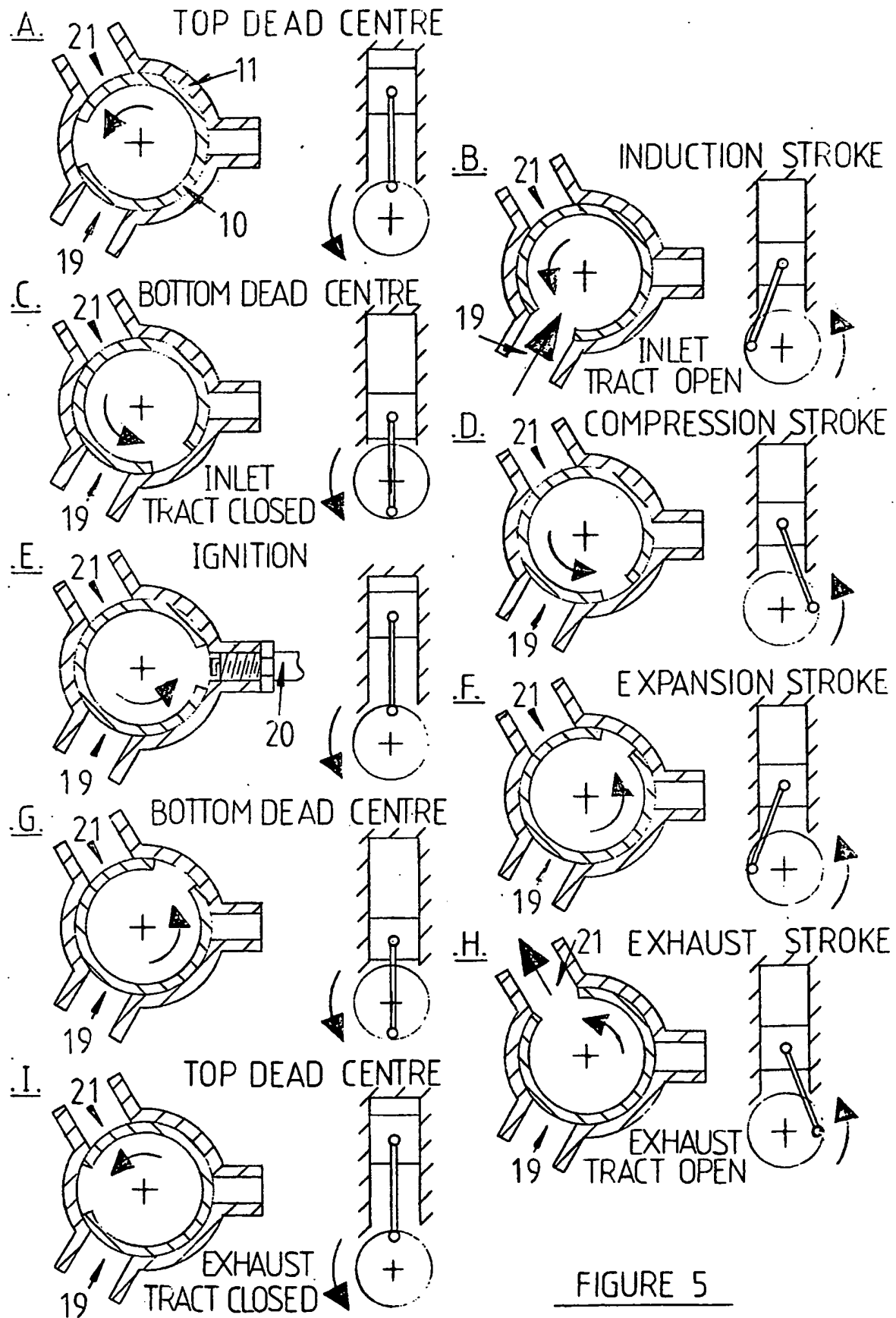


FIGURE 5

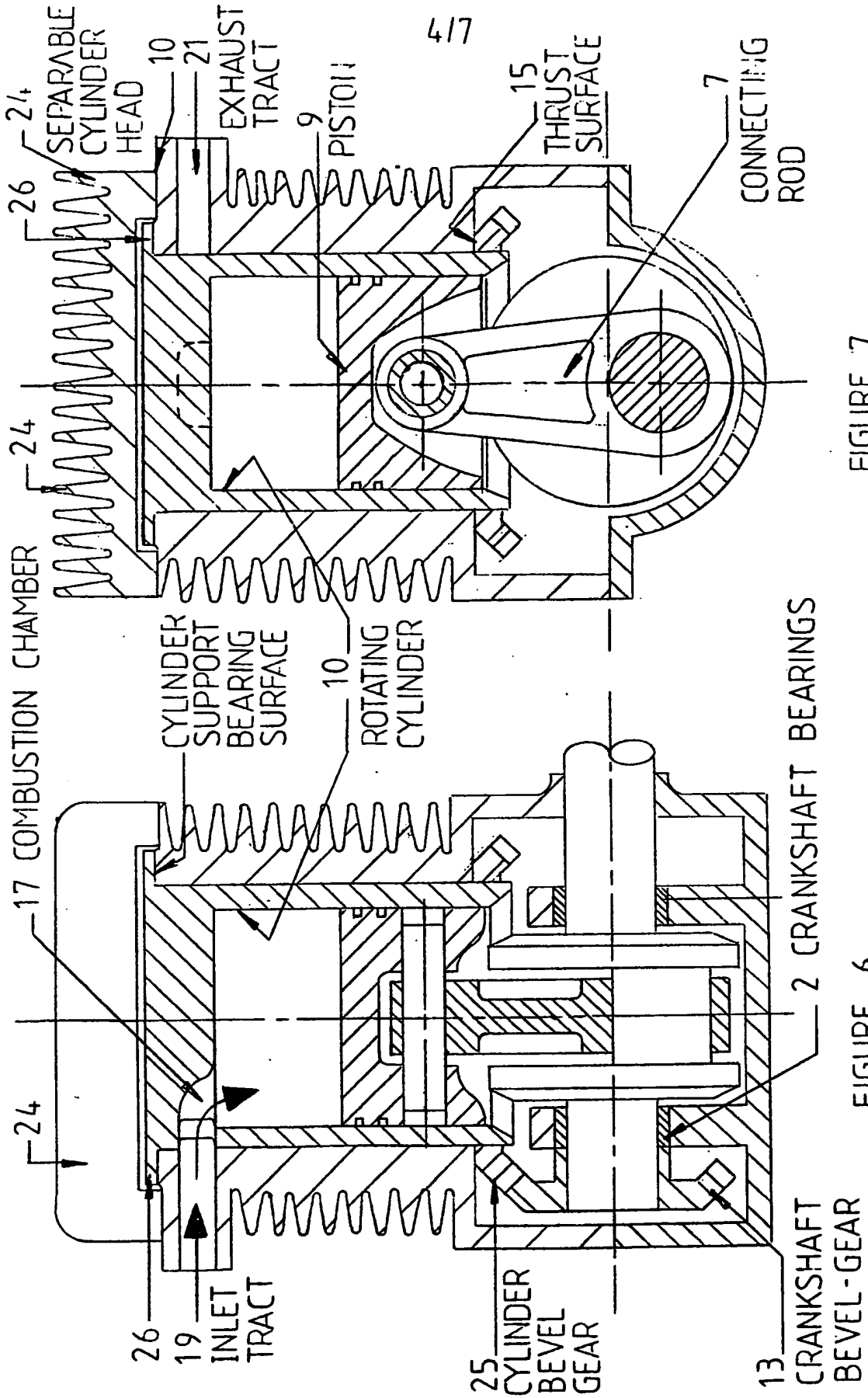


FIGURE 7

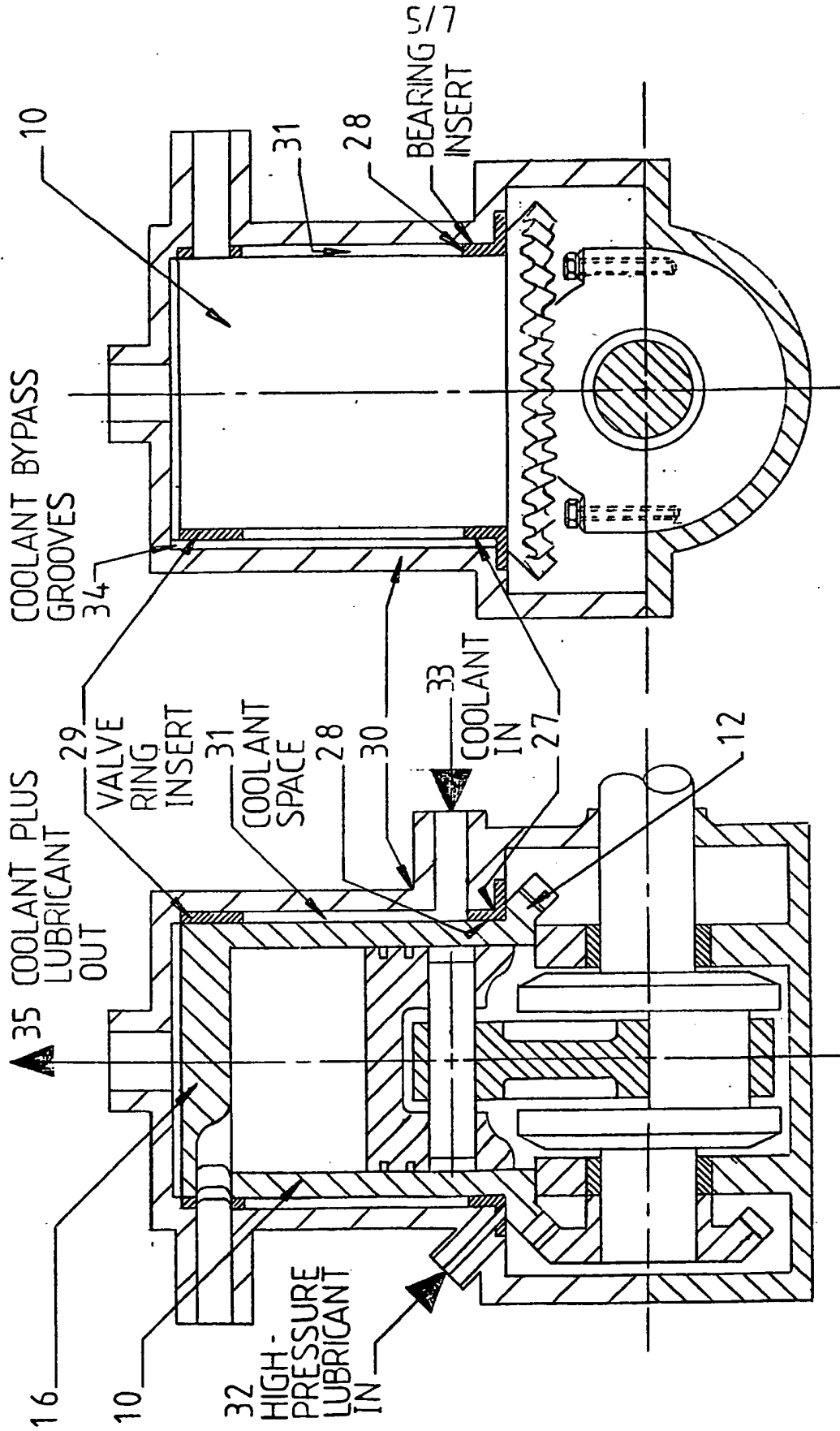


FIGURE 9

FIGURE 8

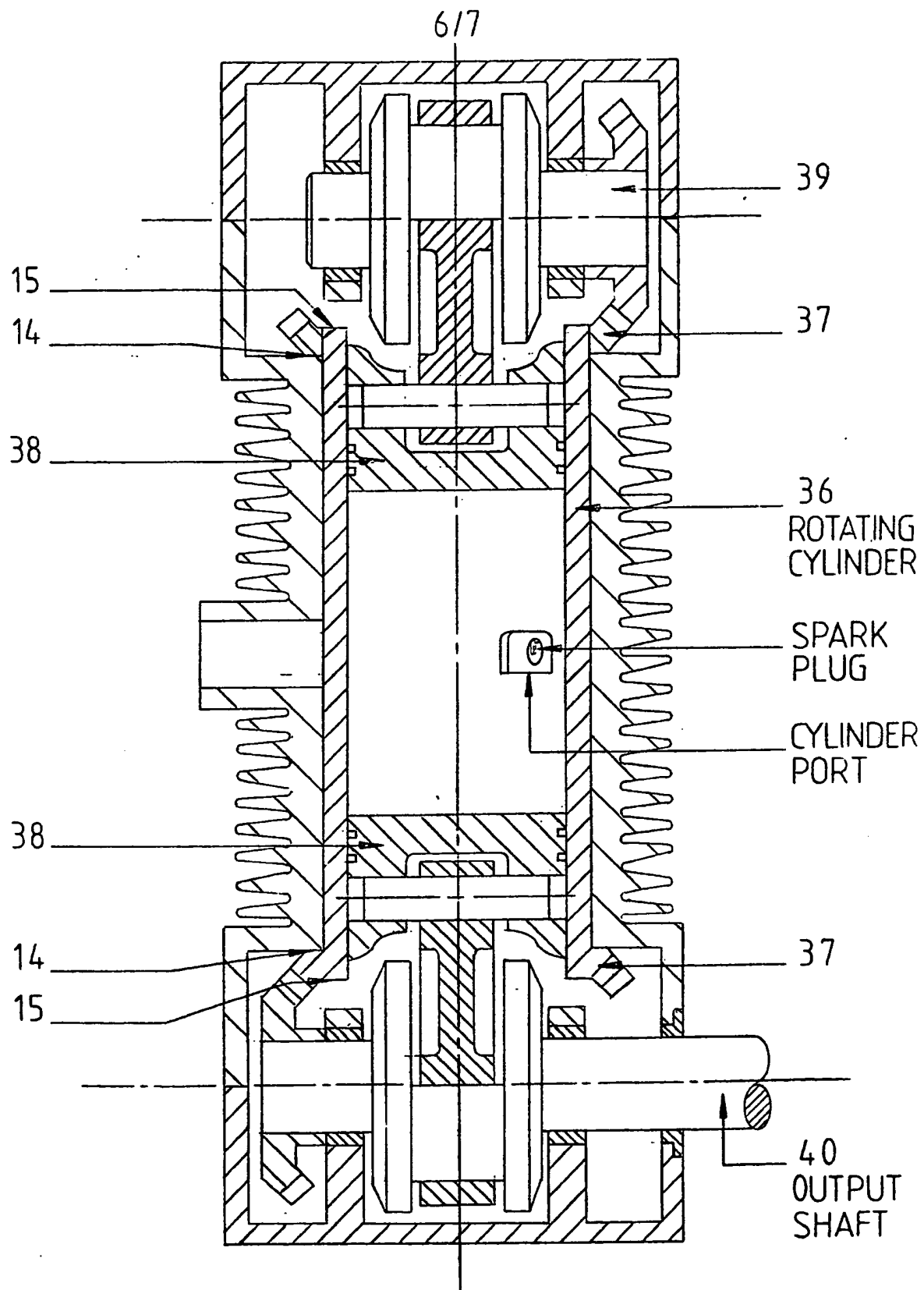
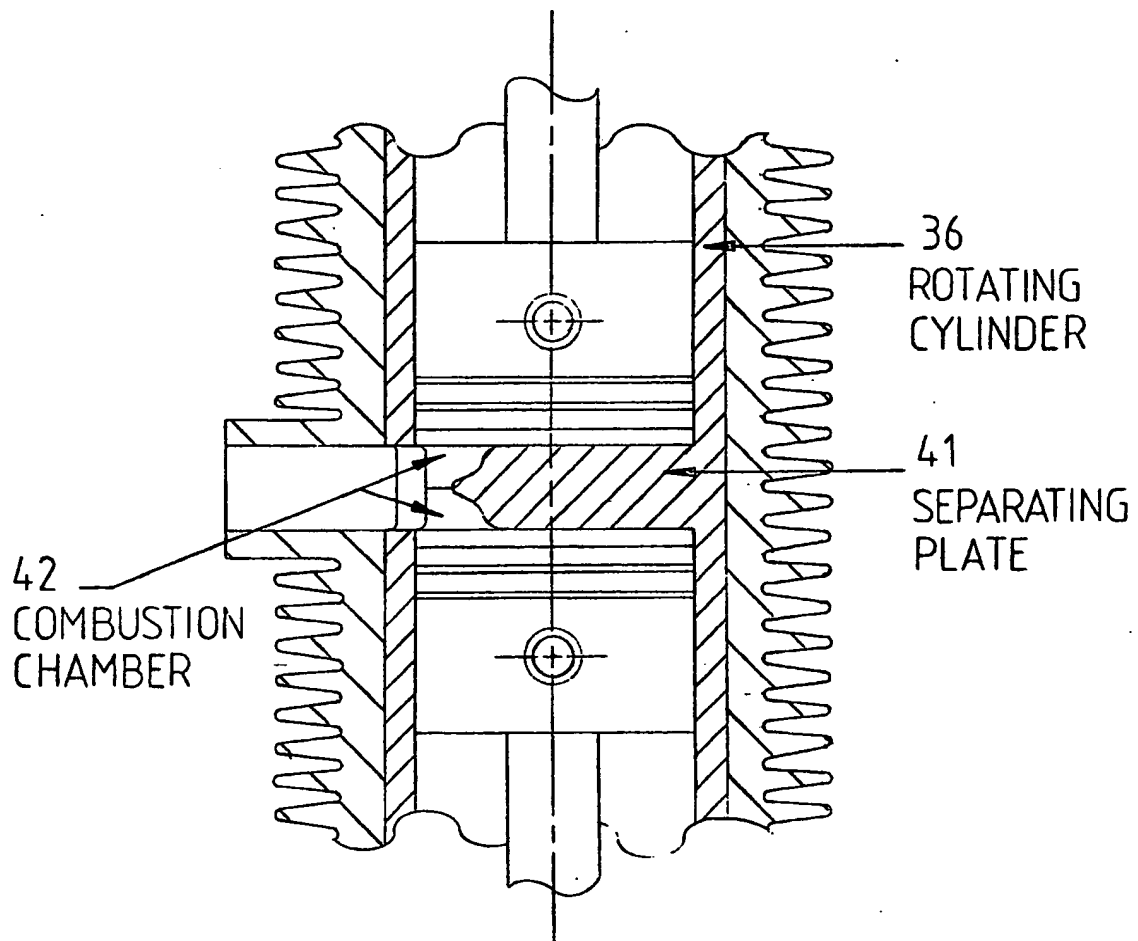


FIGURE 10

FIGURE 11

SPECIFICATION

Internal combustion engine

The invention relates to internal combustion engines. The most widely used construction of internal combustion engine embodies one or more pistons, each attached to a crankshaft by means of a connecting rod, and each free to slide in a cylinder such that rotation of the crankshaft produces a reciprocating motion of each piston in its respective cylinder. Conversely, a reciprocating movement of each piston, caused by, for example, the pressure of an ignited combustible mixture acting on the top surface of the piston, produces a rotational motion of the crankshaft. In order to produce useful power by means of a continuous rotational motion of the crankshaft, it is necessary to regularly admit a combustible mixture into the cylinder above the piston, compress the mixture by the upward motion of the piston, ignite the combustible mixture to provide a force on the top of the piston, which force produces a downward motion of the piston, which imparts a rotational motion to the crankshaft. It is then necessary to expel the burnt mixture from the cylinder, admit a fresh mixture, and repeat the sequence regularly, hence producing the desired continuous rotation of the crankshaft.

The induction of the fresh and burnt gases and vapours into and out of the cylinder requires a system of valves to control the flow of fresh mixture and combustion products into and out of the cylinder. In the type of engine generally known as the four-stroke engine, the valve system usually comprises reciprocating "mushroom" or "poppet" valves inset into the cylinder head. These valves are usually held closed by springs, and are opened at the appropriate times by arrangements of cams, or cams and levers, or cams and push-rods and levers, driven, through a gear arrangement or some equivalent system, from the crankshaft.

Whilst this valving system is the most popular for the four-stroke engines, it has become widely recognised that the system has inherent deficiencies which impose limitations on the efficiency and performance capabilities of such engines. Typical of these deficiencies are (a) power limitation due to the fact that the poppet valve system limits the speed with which an engine of given size can operate (b) thermodynamic efficiency limitation due to the fact that the existence of a hot exhaust valve in the cylinder limits the compression ratio which can be used with a given engine and fuel (c) the complexity system and the relatively large number of components involved have detrimental effects on the cost, reliability, weight, bulk and ease of maintenance of such engines.

Various attempts have previously been made to improve the performance of the reciprocating piston four-stroke internal combustion engine by eliminating the reciprocating "mushroom" or "poppet" valves. Notable examples of prior art are (1) sleeve-valve engines, and (2) Aspin-valve engines.

In a most successful design of sleeve-valve engine, the poppet-valves are replaced by a thin cylindrical sleeve which is interposed between the normal reciprocating piston and the cylinder wall. The sleeve is suitably geared and jointed to the crankshaft which thereby imposes a reciprocating and semi-rotational motion on the sleeve relative to the cylinder wall. A hole or holes in the sleeve alternatively cover and uncover passages in the cylinder wall through which the incoming and exhaust gases pass at appropriate times during the operating cycle, thus achieving the functions of inlet and exhaust valves.

The concept of the sleeve-valve engine was developed to a high degree during and after the Second World War for military applications, particularly aircraft engines. Such engines became renowned for their high power outputs, reliability, and fuel economy, but were thereafter obsoleted for aeronautical applications by the development of the turbo-jet engine. Sleeve-valve engines saw no significant development in domestic fields such as automobiles primarily because of their cost and the fact that the "poppet-valve" engine provided an adequate performance in times when fuel was cheap and fuel economy was not an overriding factor.

In the Aspin-valve engine, a concave conical surface is machined into the cylinder head where the combustion chamber would normally be. Inlet and exhaust tracts and a spark-plug hole are led into the surface of the cone. The combustion chamber comprises a tract communicating the conical outside surface and the generally flat, circular base of an otherwise solid cone of metal which locates in the aforementioned conical surface machined into the cylinder head. An extension of the cone passes through the apex of the concave conical surface in the cylinder head, on which are located bearings, a gear and other appropriate location devices. The gear is driven by the crankshaft by means of a suitable gearing system, so that the otherwise solid cone of metal containing the combustion chamber is rotated about its axis at half the speed of the crankshaft. During its rotation, the combustion chamber alternatively communicates with the exhaust tract, the inlet tract and the spark-plug in a timed sequence appropriate to the reciprocating motion of the piston in its cylinder, the complete engine operating on the four-stroke cycle principle.

Numerous prototypes have proved the concept capable of high compression ratios, high output power, and fair rotational speed. An inherent problem concerns the lubrication of the conical bearing surface. Certain minimum oil pressures are required to prevent wear and seizure. Pressurised oil inevitably blowing into the inlet and exhaust tracts causes excessive oil consumption and poor air-pollution characteristics.

In other respects this engine concept offers no advantages over the conventional poppet-valve engine in terms of cost, size, weight, reliability and ease of maintenance.

According to the invention, there is provided an internal combustion engine having at least one cylinder, a cylinder sleeve within the, or each, cylinder and a piston disposed for reciprocating motion within the, or each, cylindrical sleeve, wherein the, or each, cylindrical sleeve is constrained so that its only possible motion is rotation about its longitudinal axis, its rotational motion being produced by gearing coupling the sleeve to a crankshaft to which the respective piston is connected by a connecting rod such that said rotational movement of the cylindrical sleeve bears a predetermined relationship to the rotational movement of the respective crankshaft; and wherein the, or each, cylindrical sleeve has at least one port provided in its cylindrical surface which port(s) is movable in use into alignment periodically and sequentially with ports in the cylinder, and which the sleeve rotates, in use, for admitting gases and fuels which are to be ignited into the sleeve, and for venting products of combustion from within the sleeve and into alignment with means provided in the respective cylinder for igniting combustible material admitted into the sleeve, at appropriate times during the rotation of the sleeve and the respective crankshaft.

The advantages of an engine according to the invention are set out below.

Figure 1 is a vertical cross-section through an engine in accordance with a first embodiment of the invention;

Figure 2 is a vertical cross-section through the engine of Figure 1 when taken at 90° to the section of Figure 1;

Figure 3 is a perspective detail partly in cross-section of operating parts of the engine of Figures 1 and 2;

Figure 4 is a plan view of the engine of Figures 1 and 2;

Figures 5A to 5I are schematic representations of a working cycle of the engine;

Figures 6 and 7 are vertical cross-sections taken at 90° to one another through a second embodiment;

Figures 8 and 9 are vertical cross-sections taken at 90° to one another through a third embodiment;

Figure 10 is a longitudinal cross-section through a fourth embodiment;

Figure 11 is a cross-sectional detail of a modified version of the engine shown in Figure 10.

Similar parts in all the embodiments have been given the same reference numerals.

The crankshaft (1) rotates in crankshaft bearings (2) which are located in the lower crankcase (3) and the bearing caps (4). The bearing caps (4) are held in position by screws (5). On the crankpin (6) is mounted the connecting rod (7) which is free to rotate on the crankpin (6). The other end of the connecting rod (7) has a hole which acts as the bearing surface for the gudgeon pin (8) which locates in holes in the piston (9).

The piston (9) is thus constrained to reciprocate within the cylinder (10). The cylinder (10) is

mounted in the cylinder block (11) so that the cylinder (10) can only rotate within the cylinder block (11) with a movement whose degree bears a fixed ratio to the rotation of the crankshaft (1). In the simplest form of the invention, two rotations of the crankshaft (1) produce one rotation of the cylinder (10). At the lower end of the cylinder (10) is fixed a bevel gear (12) which may be manufactured integrally with, or detachably from, the cylinder (10). The bevel gear (12) mates with another bevel gear (13) mounted on the crankshaft (1). The bevel gear (12) is rotationally fixed to the cylinder (10) and the bevel gear (13) is rotationally fixed to the crankshaft (1). In the simplest form of the engine, the bevel gear (12) has twice as many teeth as the bevel gear (13) so that for every four reciprocating strokes of the piston (9) one revolution of the cylinder (10) occurs.

The cylinder (10) is constrained not to move significantly in a direction parallel to its axis of rotation by bearing surfaces (14) between the upper transverse surface of the bevel gear (12) and a transverse surface of the cylinder block (11) and bearing surfaces (15) between the lower transverse surface of the bevel gear (12) and the upper surfaces of the bearing caps (4).

The top of the cylinder (10) is closed off by a generally disc-shaped piece (16) which may be manufactured integrally with or separably from the cylinder (10). A recess in the disc-shaped piece (16) adjacent to the cylinder wall forms the combustion chamber (17). A port (18) is cut into the cylinder wall adjacent to the combustion chamber (17) to permit the flow of gases and fuels into and out of the combustion chamber (17) and cylinder (10). During the rotation of the cylinder (10), the port (18) aligns with inlet tract (19), spark plug (10) and exhaust tract (21) in the cylinder block (11). In the case of four-stroke Diesel or Compression-Ignition engines, the spark-plug (20) would be replaced by a fuel injector.

A small gap (22) is maintained between the cylinder cap (16) and the inner surface of the end of the cylinder block (11) so that a film of oil may be interposed between cylinder cap (16) and cylinder block (11) to act as a medium for transferring excess heat from the combustion chamber (17) and cylinder cap (16) to the cooling fins (23) at the top of the cylinder block (11). Similarly excess heat is transferred from the walls of the cylinder (10) to the cylinder block (11) by the oil film necessary for lubrication of these surfaces, and thence to the cooling fins (24) on the outer surface of the cylinder block (11). For simplicity of description, the actual lubrication system has been omitted from the foregoing diagrams.

The gap (22) also fulfills the purpose of ensuring that the longitudinal thrust produced by the high gas pressures of combustion are transferred down the length of the cylinder (10) to the bearing surface (14) which thus acts as a thrust bearing. The bearing surface (14) which accommodates this thrust is thus sited well away

from the combustion chamber, and is thus not exposed to the very high temperatures which occur near the combustion chamber. This fact has important advantages from the point of view of the life and reliability of the bearing surfaces (14). In other possible embodiments the thrust receiving surface associated with the sleeve could be provided separately of the gear (22), e.g. on an annular shoulder integral with the sleeve.

The sequence of operations of the engine is shown diagrammatically in Fig. 5.

The advantages of the above described engine are:—

- (a) the elimination of "poppet" or "mushroom" valves, particularly in the exhaust system, permits the use of much higher compression ratios before detonation or pre-ignition occurs. Higher compression ratios allow higher thermodynamic efficiencies, which yield increases in both power and fuel economy.
- b) The construction described permits the use of a very compact combustion chamber with minimal surface area, which promotes good thermal efficiency, and very small distance for flame-front propagation.
- c) The elimination of "mushroom" or "poppet" valves permits the engine to run at higher speeds, which means that more power can be extracted from an engine of given capacity and size.
- d) Compared to "mushroom" or "poppet" valves, there is relatively little obstruction to the flow of gas and fuels through the inlet and exhaust ports, which means that volumetric efficiency is improved, particularly at higher speeds of rotation.
- e) Because there are much fewer individual components in the engine described, compared with the orthodox "mushroom" valve four-stroke engine, reliability is superior.
- f) Piston and cylinder wall wear is significantly improved, because surfaces of the piston and cylinder wall are always in motion relative to each other. Even when the piston slows down and stops momentarily at the end of each stroke, the cylinder still rotates and maintains hydrodynamic lubrication at the piston/cylinder wall interface. Moreover, this hydrodynamic lubrication automatically regulates its effect in accordance with the direction of the side thrust between the piston walls and the cylinder walls as the engine goes through its cycle, in a manner analogous to a shaft rotating in a lubricated plain bearing.
- g) Because of the continual rotation of the cylinder, the heat distribution between the piston, the cylinder walls and the cylinder block is very symmetric about the axis of rotation, which minimises distortions due to localised "hot spots", and problems associated with cooling are reduced.
- h) Because of the elimination of "mushroom" or "poppet" valves and their associated operating mechanisms, the engine described has advantages in reduced size and reduced weight.

Another form of construction is shown in Figures 6 and 7 which is generally similar to the embodiment of Figure 1, except that the engine

has a detachable cylinder head (24), and the cylinder (10) is constrained longitudinally by the removable bevel gear (25) and a shoulder (26) formed at the upper end of the cylinder (10).

Yet another form of construction is illustrated in Figures 8 and 9. Here the bearing surfaces (14) are formed by the upper transverse face of bevel gear (12) and the lower transverse face of a generally ring-shaped insert bearing (27). The inner cylindrical surface (28) of the bearing (27) acts as the rotational location of the cylinder (10). The upper end of the cylinder (10) rotates in a fixed ring-shaped insert (29) which has ports cut through its cylindrical surfaces, which are aligned with the inlet and exhaust tracts and the spark-plug or fuel-injector in the cylinder block (30). In this construction there is a gap (31) between the outer cylindrical surface of the cylinder (10) and the inner cylindrical surface of the cylinder block (30). High pressure oil is fed into the oil inlet (32), thence to the bearing surfaces of the bearing (27), whence it seeps partly into the crankcase and partly into the gap (31) where it joins low pressure oil fed in from inlet (33). The low pressure oil acts as a coolant, taking heat from the outer cylindrical walls of the cylinder (10), passing via coolant bypass grooves (34) past ring inserts (29) and thence across the top surface of the cylinder cap (16) thereby cooling these items, and is then fed via the coolant/lubricant outlet (35) to an external oil cooler or radiator. The advantages of using the same oil for both cooling and lubricating purposes are twofold, viz.

- a) Mechanical simplicity, there being no need for walls, partitions and gaskets to keep coolant separate from lubricant.
- b) More freedom of thermodynamic design, where otherwise one of the constraints imposed upon the engine designer would be the boiling point of water if this were to be used as coolant.

A further alternative method of construction is illustrated with reference to Figure 10. Here the rotating cylinder (36) is open at both ends, with bevel gears (37) attached at both ends, and with two pistons (38) reciprocating within the one cylinder (36) in a generally symmetrical manner, this being generally referred to in the art as the "opposed-piston" configuration. The advantages of the engine just described is that because of its symmetrical arrangement, there is no longitudinal force imposed on the cylinder, therefore, little or no force is exerted at the bearing surfaces (14), and, therefore, a reduction in frictional losses is obtained. Because the cylinder (36) is longitudinally located by the bevel gears (37), no further location at surfaces (15) is required. Since one inlet tract and one exhaust tract serves two piston, for a given gas velocity in the inlet and exhaust tracts a larger cross-sectional area of tract is required than if only one piston were being served. The ratio of cross-sectional area to length of cross-sectional-periphery is thus larger, which means that less wall friction is experienced by the flowing gases, which provides improved

volumetric efficiency for this configuration, particularly at high rotational speeds. One great disadvantage of previous prior-art opposed-piston engines was the necessity of coupling the two crankshafts together with gears and cross-shafts, or other complex and bulky mechanisms. it is clear that this crankshaft coupling requirement already exists in the engine described in Fig. 10, because the rotating cylinder (36) acts as the coupling shaft between the upper crankshaft (39) and the lower output crankshaft (40). Because of the relatively large diameter of the cylinder (36), it will readily transmit power from the upper crankshaft (39) to the output crankshaft (40) without undue stress.

An improvement in combustion efficiency is obtained in the "opposed-piston" configuration when a disc-shaped insert (41) as shown in Figure 11 is fixed centrally and symmetrically in the rotating cylinder (36), with two similarly shaped communicating recesses (42) forming the combustion chamber. The recesses (42) are shaped so as to provide a substantially equal distribution of gases and fuel induced into the internal sections of the rotating cylinder (36) on respective sides of the insert (41).

Many modifications are possible to the above described embodiments without departing from the scope of the invention as defined in the accompanying claims. It will be appreciated that a wide range of air-cooled, water-cooled, or oil-cooled single or multi-cylinder engines can be produced in accordance with the invention. Indeed it is possible to replace or reproduce virtually any conventional internal combustion engine of the reciprocating piston type by a similarly configured engine embodying the invention. Moreover the sleeve may be coupled to the respective crankshaft in other ways than the direct gear coupling shown in the above described embodiments. It may in some engine designs be advantageous to use more complicated gearing systems, e.g. incorporating idler gears or epicyclic gear trains.

45 CLAIMS

1. An internal combustion engine having at least one cylinder, a cylindrical sleeve within the, or each, cylinder and a piston disposed for reciprocating motion within the, or each, cylindrical sleeve, wherein the, or each, cylindrical sleeve is constrained so that its only possible motion is rotation about its longitudinal axis, its rotational motion being produced by gearing coupling the sleeve to a crankshaft to which the respective piston is connected by a connecting rod such that said rotational movement of the cylindrical sleeve bears a predetermined relationship to the rotational movement of the respective crankshaft and wherein the, or each, cylindrical sleeve has at least one port provided in its cylindrical surface which port(s) is movable in use into alignment periodically and sequentially with ports in the cylinder, in which the sleeve rotates, in use, for admitting gases and fuels

65 which are to be ignited, into the sleeve, and for venting products of combustion from within the sleeve, and into alignment with means provided in the respective cylinder for igniting combustible material admitted into the sleeve, at appropriate times during the rotation of the sleeve and the respective crankshaft.

2. An internal combustion engine as claimed in Claim 1, wherein said sleeve, at or adjacent an end thereof adjacent a crankshaft of the engine, is provided with an annular abutment surface for engagement with an annular surface at a respective end of the corresponding engine cylinder to provide a thrust bearing at a position remote from the associated engine combustion chamber.

3. An internal combustion engine as claimed in Claim 1 or Claim 2, wherein at least one end of said sleeve adjacent a crankshaft is provided with an annular gear encircling the sleeve.

85 4. An internal combustion engine as claimed in Claims 2 and 3, wherein said annular abutment surface is formed on said annular gear.

5. An internal combustion engine as claimed in Claim 3 or Claim 4, wherein said gear is a bevel gear mating directly with a second bevel gear provided on the respective crankshaft.

6. An internal combustion engine as claimed in any of Claims 1 to 4 wherein a gear, or gear train, is interposed between said gear and a gear provided on the respective crankshaft.

7. An internal combustion engine as claimed in any preceding Claim wherein one of the said sleeve is closed by a wall generally transverse to the axis of rotation of the sleeve and at least one cavity is formed in said transverse wall adjacent to at least one port provided in the cylindrical surface of the sleeve, to provide a combustion chamber.

8. An internal combustion engine as claimed in any of Claim 1 to 4 of the proposed piston type wherein at least one pair of opposed pistons are provided with the, or each, pair of pistons being reciprocable in a common rotary cylindrical sleeve, the pistons of the, or each, said pair being connected to respective crankshafts so as to move in opposite directions to each other and a combustion chamber being formed in the space confined between the, or each, pair of opposed pistons, when at or near their top dead centre positions, and walls defined by said sleeve and the cylinder in which it is located for rotational motion as aforesaid.

9. An internal combustion engine as claimed in any of Claims 1 to 4 of the opposite piston type, wherein at least one pair of opposed pistons are provided with the, or each, pair of pistons being reciprocable in a common rotary cylindrical sleeve, and pistons of the, or each, said pair being connected to respective crankshafts so as to move in opposite directions to each other, and wherein a transverse wall is provided centrally in the sleeve dividing it in to two similar sections each containing one of said pistons, a recess being provided in each side surface of the transverse wall with the recesses communicating with one

- another to define a combustion chamber when the pistons are at or adjacent their top dead centre positions, and with the recesses also communicating with said port in the cylindrical wall of the sleeve and being shaped so as to provide a substantially equal distribution of gases and fuel induced into the internal sections of the sleeve on respective sides of said transverse wall thereof.
- 10 10. An internal combustion engine as claimed in Claim 8 or Claim 9 wherein the common sleeve has gear means at each end thereof which form a gear coupling between the sleeve and each of said crankshafts.
- 15 11. An internal combustion engine as claimed in any preceding Claim wherein spacer means are provided to define an annular space between the outer periphery of the, or each, sleeve and the wall of the cylinder in which it is disposed over the majority of the length of the cylinder so as to provide a space for the passage therethrough of a coolant.
- 20 12. An internal combustion engine substantially as hereinbefore described with reference to, and as illustrated in, Figures 1 to 5 or Figures 6 and 7, or Figures 8 and 9, or Figure 10, or Figure 10 as modified and shown in Figure 11, of the accompanying drawings.
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